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The Evolution and Special Features of Bell System Telephone Equipment Buildings

By W. PFERD

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There are slightly over 20,000 telephone buildings that house the switching and transmission equipment of the Bell System telephone network. These structures provide a dedicated operational environment for the communication equipment by employing special-purpose mechanical, electrical, and structural systems. Although varying greatly in size, similiar systems appear in all modern central offices and transmission stations. The special systems are required to interconnect the cable and wire, to support and protect the equipment, to power the circuits, and to properly control the spatial environment. This paper describes the 100-year evolution of the standards that control the design of the various classes of Bell System telephone equipment buildings and the sequence of actions necessary to plan and construct a modern facility. Also included is detailed information about the more important aspects of the equipment-building systems, along with numerous photographs that illustrate the special features.

I. INTRODUCTION

Telephone company equipment buildings, known generically as wire centers, central offices, and transmission stations, are geographically placed and specifically designed and constructed to function as effective parts of the nationwide telephone network. As a result, the planning of such facilities requires different considerations than those found in conventional architectural and building design activities. The basic purpose of a telephone equipment facility, and therefore the primary objective in its design, is to provide the appropriate assembly of equipment, cable, wire, and control, operation, and support systems within a protective enclosure to satisfy the needs for local and nationwide telephone service. The enclosure, equipment, and circuits are so tightly interrelated that they are commonly identified as an equipment-building system.

This paper describes the various classes of telephone equipment buildings in the Bell System and the evolution of the design standards for the modern central office and transmission station. The sequence of events that occur in the planning and construction of a new equipment building is presented and is followed by information about the special design and construction of the electrical, mechanical, and structural portions of central offices and transmission stations.

II. TELEPHONE EQUIPMENT FACILITIES

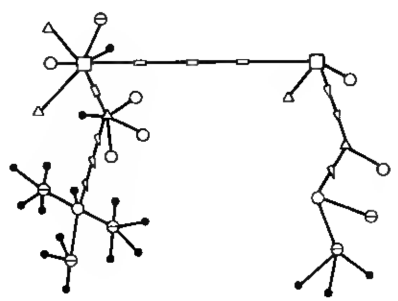
The interconnection of almost 160 million telephones across the North American continent is possible because of complex switching equipment and circuits located at nodes in the nationwide network.[1] Typically, thousands of wires in aerial and underground cables come together at each switching node location. The cables and related apparatus, such as utility poles, conduits, and manholes, are called outside plant. To minimize outside plant costs, the wires leading to a node must converge to a small geographic area which defines the most economical location from which all customers in an area can be served. At the node, the term "wire center" is consequently often used to designate the end portion of outside plant, the apparatus, the interconnecting equipment, and the support structure at that location.

More important than the terminology, however, is the function of these facilities, for they are the means by which telephones and data sets are connected to one another. It is the wire center, or central office, that provides the dial tone on the calling customer's telephone and provides the connection to the line (pair of wires) of the called party. The two telephones are connected through a maze of wiring by switching equipment located in the central office. In other cases, the calling and called customers are served by equipment in different wire centers or are connected to wire centers through a toll office that serves different geographical locations. When these locations are a considerable distance apart, the call will be routed through the nationwide network that comprises hundreds of toll-switching offices widely distributed yet interconnected with high-message-capacity transmission facilities. The network is engineered so that calls processed from one toll office to another will be routed automatically to utilize the transmission facilities as efficiently as possible. If the call is blocked due to overload at some intermediate location, alternate routes are chosen sequentially, and the call is completed through different toll offices and transmission routes. Thus, numbers of central offices or toll offices are needed to process long-distance calls, and they are located especially to serve called and calling customers and the connecting routes.

The nationwide network contains a hierarchy of five classes of offices in which the lowest (class 5) is the local office to which

telephones are connected. For toll calls, several class 5 offices that are in contiguous geographic areas may each be connected to a single class-4 office or one of higher rank (lower number) in much the same manner that several thousand customers are each connected to a single local office except that toll circuts, rather than outside plant pairs of wires, are used. A class 4 or higher toll office is, therefore, the switching node and the wire center for a group of class 5 offices. In similar fashion, a group of class 4 and class 5 offices is connected to a single class 3 office, a group consisting of classes 3 to 5 is connected to a class 2 office, and a group consisting of classes 2 to 5 is connected to a class 1 office. The general scheme is shown symbolically in Fig. 1, where a connection is traced from one local office to another, through the intervening lower numbered offices in the hierarchy. The locations of the class 1, 2, and 3 offices in the Bell System are shown on the map in Fig. 2. In addition to the offices classified in tbe hierarchy, there are tandem offices used exclusively to switch calls between offices in the same region. In summary, there are three general types of central offices listed in five classes. Essential to the interconnection of customers are the different local, tandem, and toll offices. In the hierarchy are local class 5 offices and toll class 4 to 1 offices. Each is a vital element in the Bell System's telephone network.

In addition to the central offices, the other special-purpose structures shown in Fig. 1 between the class 1 to 3 offices enclose equipment that is associated with radio, satellite, and cable transmission facilities. Repeater, power-feed, and main equipment-building systems, known



LEGEND

SYMBOL	CLASS	NAME
□	1	REGIONAL CENTER
△	2	SECTIONAL CENTER
○	3	PRIMARY CENTER
⊖	4	TOLL CENTER
•	5	LOCAL OFFICE
▭		TRANSMISSION STATION
◁		RADIO REPEATER STATION

Fig. 1—Switching hierarchy in two regional areas.

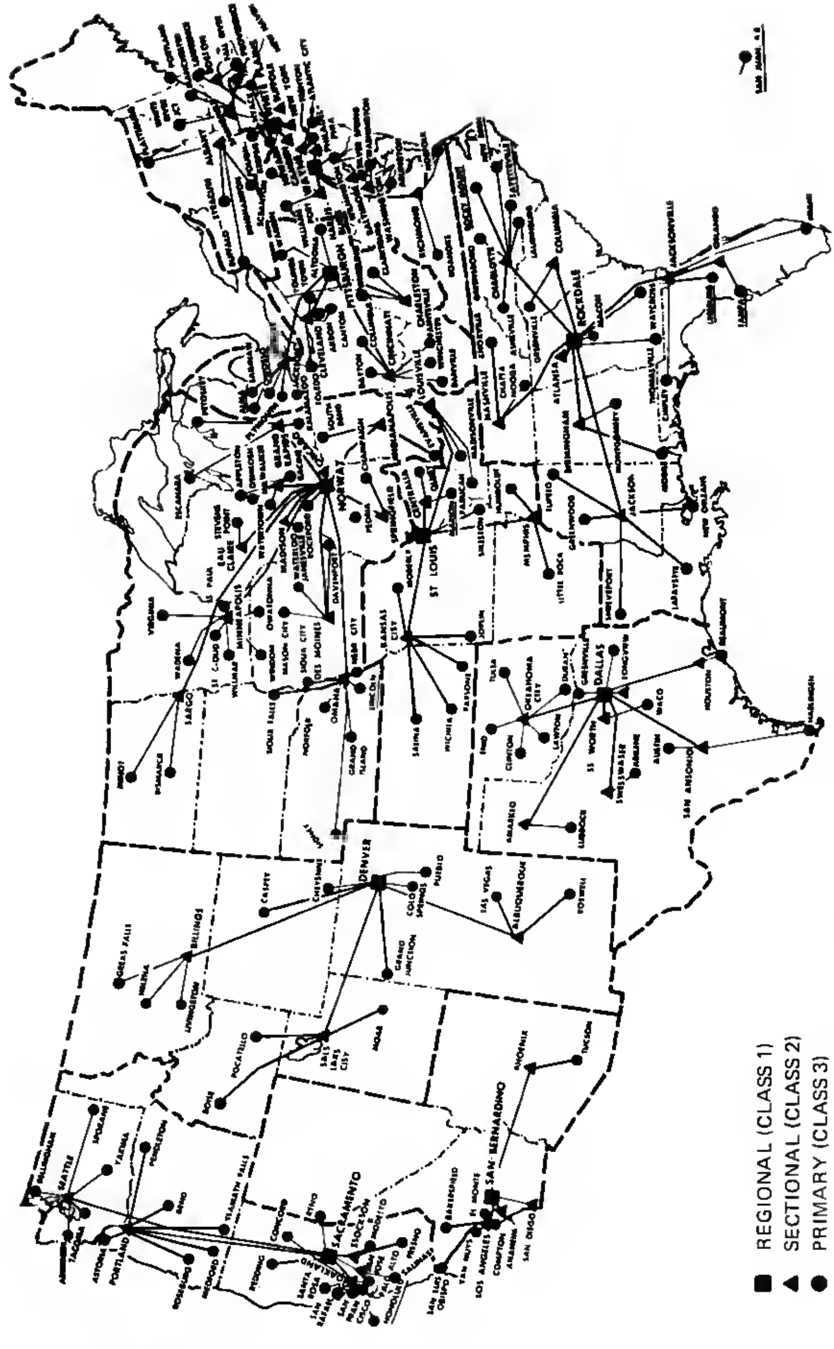


Fig. 2—Locations of regional, sectional, and primary switching centers in the toll network.

generically as transmission stations, are placed regularly along the connecting routes. Main transmission stations, located near metropolitan areas, are large in size and contain equipment, power, and support systems necessary to connect toll offices in nearby cities to the circuits of the long-distance transmission facility. Whether the facility is wire, lightguide, coaxial cable, waveguide, or point-to-point microwave radio, the transmitted signals must be amplified every few miles, the specific distance depending on the type of system. Repeater equipment installed in manholes, in cabinets at the bases of antenna towers, or in special-purpose structures provide the required amplification. Repeater transmission stations have floor-plan areas that are typically 1000 square feet. All provide power and a protective environment for the transmission equipment. The repeater equipment on the coaxial cable routes is powered through the coaxial cable from dc plants located in power-feed transmission stations. These stations are about 6500 square feet in area, are usually underground, and are spaced approximately 75 miles apart on routes which traverse the nation.

The building portions of the system provide the essential environment, power, and structural support for the installation and operation of the telephone circuits and equipment. Based on long-range plans, the building must accommodate, in various stages of growth, the installation of equipment and the interconnection of circuits and must provide control of the environment within the building. The "environment" includes the temperature, humidity, and purity of the internal space needed for proper functioning of the telephone equipment and circuits. Additionally, it includes highly specialized spatial and structural arrangements for routing miles of power and communication wire and cable to interconnect the various units of telephone equipment in three-dimensional (e.g., both interfloor and intrafloor) lattices. Also, special construction may be required to prevent malfunction of equipment by penetration of stray electromagnetic and electrical fields.

The planning for an equipment-building system consists of three stages—first, the establishment of long-range circuit forecasts; second, the determination of the means by which they will be achieved; and finally, the design and construction of the facility. Preceding any architectural design are the important and painstaking tasks of selecting the optimum geographic location for the proposed equipment-building system and making complete plans that identify the telephone equipment's physical and operational characteristics, interconnecting cable-length requirements, compatibility with future expansion of the facility, and supporting subsystems such as the reserve power and equipment-cooling machinery. The outputs of the planning stages, that is, the forecast, the location of the facility, the equipment plan, the cabling plan, and the requirements for electrical, mechanical, and

structural support, provide the basis for the construction drawings and specifications that are prepared by the architect/engineer.

In summary, all the Bell System's equipment buildings can be placed in one of two categories: central office and transmission station. The central offices are local, tandem, toll, and various combinations called multi-entity offices, while the transmission stations are repeater, power-feed, and junction or main. There are slightly over 11,500 central office buildings that serve as nodes in the nationwide telephone network and close to 9000 transmission stations located along the transmission routes. Of the two general types of equipment buildings, the central offices are the most varied, ranging in size from the smallest (400 square feet) to the largest (1 million square feet) structures in the Bell System. In total, the Bell System equipment buildings contain about 230 million square feet of floor area for equipment and support systems.

III. EVOLUTION OF THE MODERN TELEPHONE EQUIPMENT BUILDING

Telephone technology has experienced a vast amount of change since its inception 100 years ago, including the way in which telephone buildings are designed and used. At first, the building was simply a place to interconnect jumper wires. Later, this awkward-to-use system was replaced with manual switchboards that had cords fitted with plugs for operator usage. By the end of the nineteenth century, automatic connection systems were in development, but it was not until the 1920s that switching machines, called entities, were introduced into the buildings. By 1930, 9 percent of the Bell System's offices were dial; by 1940, the figure had grown to 38 percent. The shortages of material and manpower resulting during World War II reduced temporarily the rate of conversion to dial, but activity was renewed in 1945, and by 1960, 94 percent of the central offices were dial. Most of the Bell System's manual central offices were retired during the change to automatic dial service. Table I contains a tabulation of the types of central offices in service between 1950 and 1977.[2] Four types of switching equipment are involved: step-by-step, panel, crossbar, and elec-

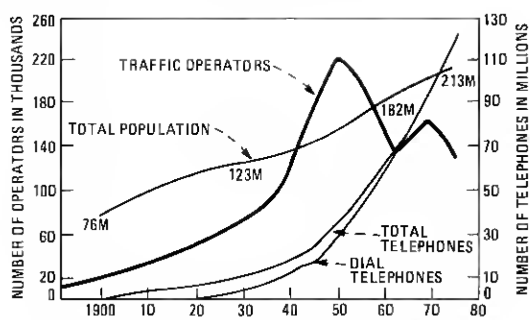
Table I—Number of central office codes

Dec. 31	Manual	Panel	S × S	X-Bar	ESS	Total*
1950	3,257	502	4,107	604		8,470
1955	1,991	512	6,087	1,161		9,751
1960	715	494	7,511	2,258		10,978
1965	94	528	8,212	4,281	1	13,121
1970	11	451	8,393	5,637	264	14,756
1975	1	144	7,911	6,549	2,183	16,788
1977	1	68	7,223	6,537	3,477	17,306

* Some buildings are multi-entity facilities containing more than one central office code. Therefore, the number of Bell System central offices exceeds the actual number of central office buildings.

tronic. During the last five years, new offices have been almost entirely of the advanced electronic type that operates automatically for the processing of calls.

As telephone usage by the general public grew through the years and the demand for increased service materialized, more complex central offices and transmission stations were needed. This was the basis for telephone company growth and modernization programs that cause the network today to have such a large number of offices and stations. During the 55 years of steady growth in usage of switching and transmission equipment, the extent of operator assistance has undergone dramatic changes which have also influenced the design of equipment building. Figure 3 shows the number of traffic operators along with the number of dial telephones and the total population for the years 1890 to 1975.[2] Because of the change from a manual to a mechanized mode of operation for toll calling that was made possible by crossbar central offices, the number of operators in the Bell System declined after 1950. By 1960, the number began to increase again in response to the increase in special toll calls needing operator assistance. After 1970, improvements in call processing made possible by the Traffic Service Position System (TSPS) caused a second decline in the number of operators. TSPS comprises electronic equipment at local and toll offices connected by circuits to operator consoles installed in administrative-type space. Typically, the equipment and the operators are located in different buildings. This arrangement offers the advantage of concentrating the operator activity for efficient call processing, and operators can be located in less expensive conventional office buildings rather than in equipment buildings. The switchboards replaced by these TSPS consoles are the last items requiring heavy personnel staffing within a central office. As a consequence of the introduction of TSPS during the past ten years, all new central office buildings are now designed primarily for equipment.



REDUCTIONS IN TRAFFIC OPERATOR REQUIREMENTS IN 1950 AND 1970 RESULTED FROM THE INTRODUCTION OF DIRECT DISTANCE DIALING AND FROM THE TRAFFIC SERVICE POSITION SYSTEM RESPECTIVELY.

Fig. 3—Bell System growth compared to total population growth.

The long-term trend toward central offices with few human occupants has been accelerated further by the introduction of automated maintenance equipment. This has occurred during the last 25 years with crossbar and electronic offices where fewer personnel are required due to machine-controlled self-diagnosis and repair procedures. In modern switching machines, checks on performance are made automatically, problems are diagnosed and reported on a teletypewriter printout or cathode ray tube for correction. In some cases, the malfunctioning parts are automatically disconnected from service and the needed replacement parts are identified along with the trouble-alert information. Similarly, computerized automatic maintenance systems are also used for remote-surveillance and testing of equipment associated with the other functions of a central office, namely, subscriber loop plant, trunks, carrier systems, and special services. At the present time, over 60 centralized maintenance systems exist to serve the equipment along with providing administrative records for the facilities and circuits.

A specific example of a modern facility that is designed for few occupants is the electronic toll office at Rego Park in Queens, New York. This multi-story structure contains about 200,000 square feet, has an ultimate capacity of approximately 100,000 toll-line terminations handling over 500,000 busy-hour calls, but will require only about 60 people for operation of the telephone equipment systems. In contrast, if the previous generation of switching equipment had been used, 425 operating personnel would be required and, although it is not technically possible to use manual cord-type switchboards of this capacity, an office handling this many calls would require approximately 2300 operators.

The trend toward increased size and full automatic operation also appears in the transmission stations. The first toll routes were limited to only a few telephone conversations (channels) per pair of wires. Analog carrier systems, introduced in 1941, could accommodate 600 channels per coaxial cable pair or 1800 channels in a cable of eight coaxial tubes with repeater stations about 20 miles apart. With innovations introduced over the years, it is now possible to accommodate over 10,000 channels on a single coaxial pair and over 100,000 channels in a cable sheath containing 22 coaxial tubes. Similarly, the channel capacity of radio relay systems has grown over the years as a result of advances in circuit and antenna technology. An important consequence of the increase in cable and radio system capacity is reduced expenditure per channel; however, this has increased the amount of equipment in transmission stations and has required more stations on a route. Funds that would have otherwise been invested in cable plant have, therefore, been used for equipment-building systems. Because of the number and the geographic locations of the transmission stations at

remote sites, the use of complex equipment for monitoring and control purposes is necessary. The result is virtually unattended operation of all radio and cable transmission stations. Only main or junction stations require assigned craftspersons. Typically, less than a dozen craftspersons can operate the largest of the main stations and, thereby, the building can be designed almost entirely for equipment purposes.

The conversion from manual operation to dial service and from attended to automatic systems has also caused a change in the characteristics of the interior space used for equipment interconnection. The automatic switching and transmission equipment introduced physical and environmental requirements that were entirely different from those of the manual switching offices. Previously, the labor-intensive activities of operators demanded an office-type environment. Interestingly, the term "office" that originated during this period is still associated with the modern switching center. The change from office-type space to equipment space for growth was considered so important during the early days of dial conversion that special engineers were employed to be responsible for providing the space and structures with the features necessary for proper functioning of the switching and transmission equipment. Continuing to the present, these telephone company building engineers interact with the planning and equipment engineers to provide buildings that are designed to special standards and specifications.

During the past 100 years, Bell System telephone building standards have been established during three periods. The first standards were set before 1900 and were concerned principally with provisions for the entrance of cable into the building, shafts for running cable from floor to floor, and the long switchboards located in the operating rooms.[3] The manual service of this period required large staffs on continuous duty in the central city buildings. Additional space equal to that required for the switchboards was devoted to quarters for the operators. In some small places, the central office was also the home of the operator and his or her family. These earliest of standards resulted in offices of the types shown in Fig. 4. Many were of wood construction to harmonize with the suburban and rural areas, while those located in major cities were of multistory, fireproof office-building type design and construction.

About 1925, AT&T engineers studied the problem of standardizing equipment and buildings in anticipation of the introduction of electromechanical switching equipment. At that time, the frames on which equipment units were mounted varied in height from 9 to 14-½ feet. High ceilings for temperature control were common, and cabling was relatively simple. As a result of this second study, the Bell System adopted a standard of 11-½ feet for the height of equipment frames. These so-called high bay requirements, which at that time made best

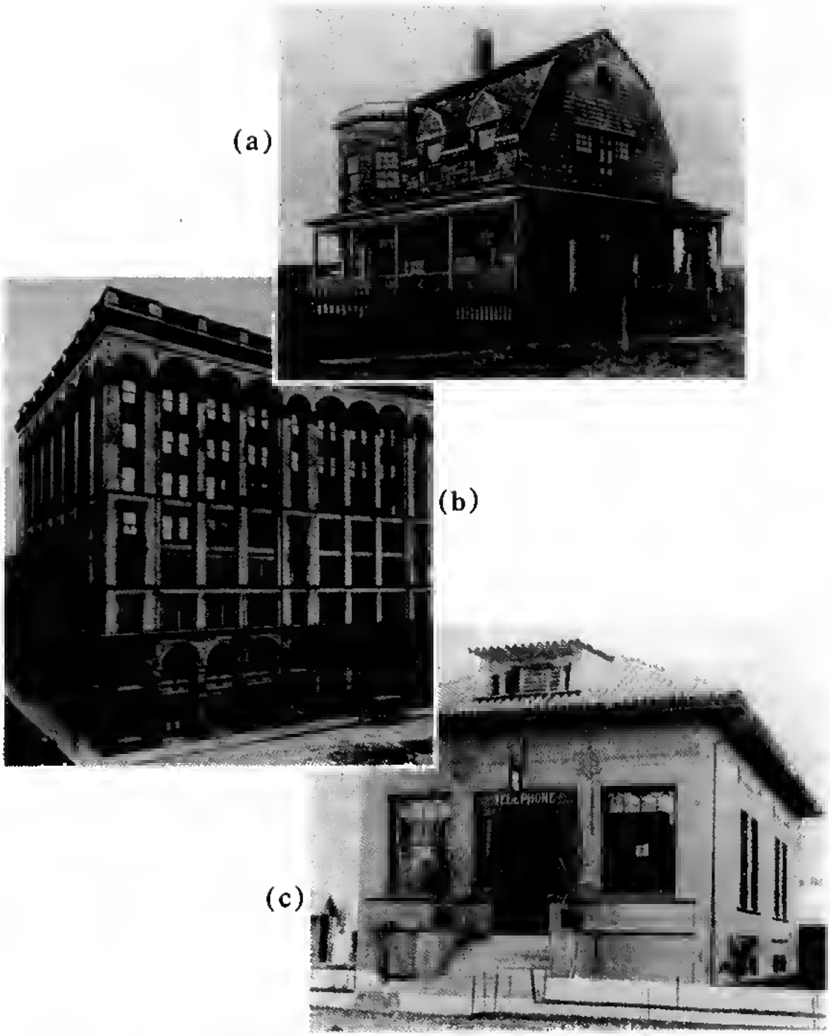


Fig. 4—Pre-1900 Bell Telephone central offices. (a) Typical country exchange with manager's dwelling above. (b) Main telephone office. (c) Local exchange.

use of building space, held until the mid-1960s and dealt exclusively with providing structural, spatial, and cabling accommodations for tall frameworks that characterize electromechanical switching systems. During the years 1925 to 1965, over 10,000 central offices and transmission stations were constructed to the high bay standards. Typical buildings of this era are shown in Fig. 5. All are fireproof, have high ceilings, and are of heavy construction to support the heavy, tall frames of equipment and large bundles of interconnecting cable. Most were designed for occupancy by craftpersons and the larger ones also provided space for operator service.

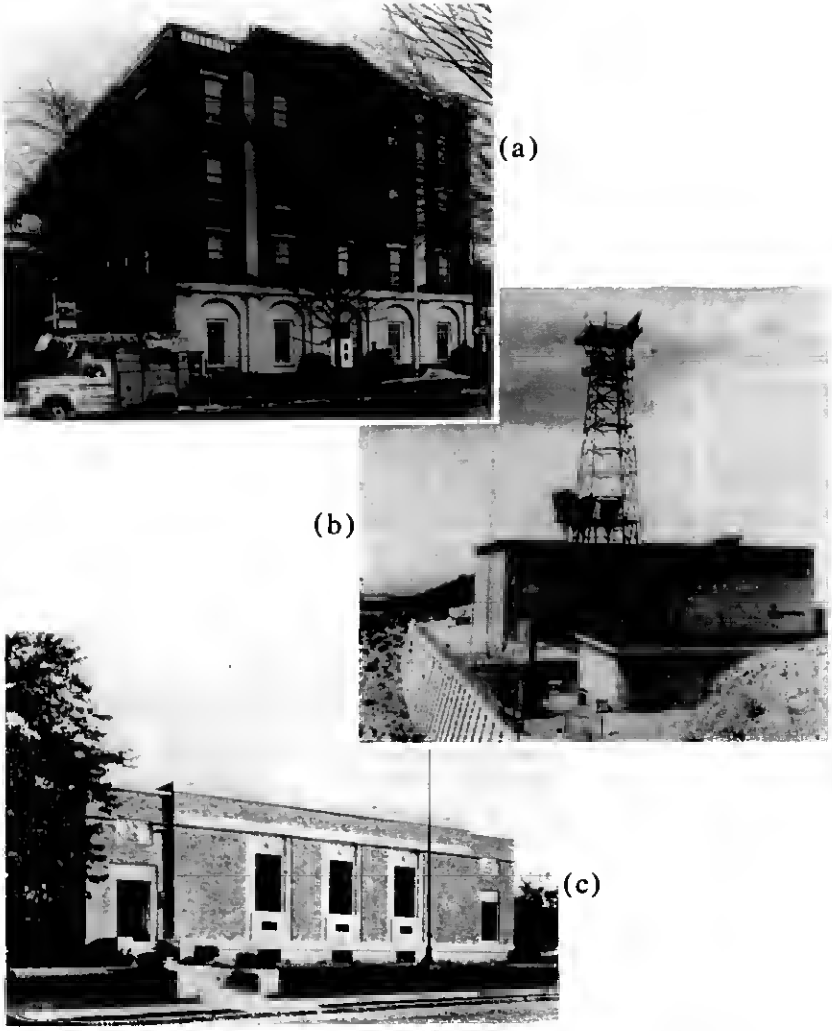


Fig. 5—Structures erected, from the 1930s to the 1960s, for tall equipment. (a) Large multi-entity office. (b) Mountaintop radio repeater station. (c) Local central office.

With the introduction of the Electronic Switching System (ESS) equipment in 1965, studies were again undertaken to assess the need for alternative standards for equipment buildings. The miniaturization of circuit elements in the electronic equipment enabled capacity and features never before attainable in switching and transmission systems; however, the individual assemblies exhibited unprecedented heat, cabling, and weight concentrations. Consequently, the third look at equipment building standards was undertaken.[4] A building and equipment task force representing all systems development areas of Bell Laboratories was convened to study and to recommend appropriate

new standards. The task force devised a third group of complementary specifications for equipment and buildings that are contained in the New Equipment-Building System (NEBS) documents: (*i*) tbe *Equipment Design Standards,* BSP 800-610-164 for Bell System use and PUB 51001 for the general trade, provide the spatial and environmental performance requirements for all new equipment systems, (*ii*) the *Building Engineering Standards* (BSP-760-100-xxx and 760-200-xxx) specify the planning and design of buildings to adequately accommodate the modern equipment, and (*iii*) the *NEBS Catalog* lists Western Electric equipment to be installed in these facilities.

The latest in the series of Bell System building standards was adopted for use in the design of all local offices after 1972 and for all other types of central offices and transmission stations after 1974. Examples of equipment buildings constructed to NEBS standards are shown in Fig. 6. They are characterized by large windowless rooms for equipment, with associated space for elaborate environmental control and reserve power systems. Features such as these, plus the designated locations of the office at the wire center, the provisions for extensive interconnecting cable systems within the structure, and the provisions for only limited human occupancy, are typical of the modern equipment facility.

IV. NEBS STANDARDS

Equipment building standards are important not only to the performance of the facility but also to the cost of buildings since each of the physical characteristics of telephone equipment has a corresponding effect on the design of the building intended to house that equipment. Frame height and cabling space, for example, control the so-called "clear" ceiling height from floor to lowest overhead obstruction. Equipment weight determines the building's "live load," the weight that foundations, columns, and floors must support in addition to their own weight. The amount and location of heat emanating from the equipment sets the size of the cooling plant and the location of the air ducts and diffusers. But when equipment units differ greatly, the variations in their physical characteristics prevent the efficient use of space in telephone buildings and complicate the already difficult task of office planning and design. In the absence of uniform standards, space in equipment buildings must be engineered to meet the most severe requirements and to accommodate the widest possible range of conditions. The result is costly designs with dubious performance capability.

To avoid these complications, the NEBS standards include the full range of spatial and environmental conditions. The requirements cover equipment frame areas, distributing frame areas, power equipment areas, operations support systems areas, cable distribution systems,

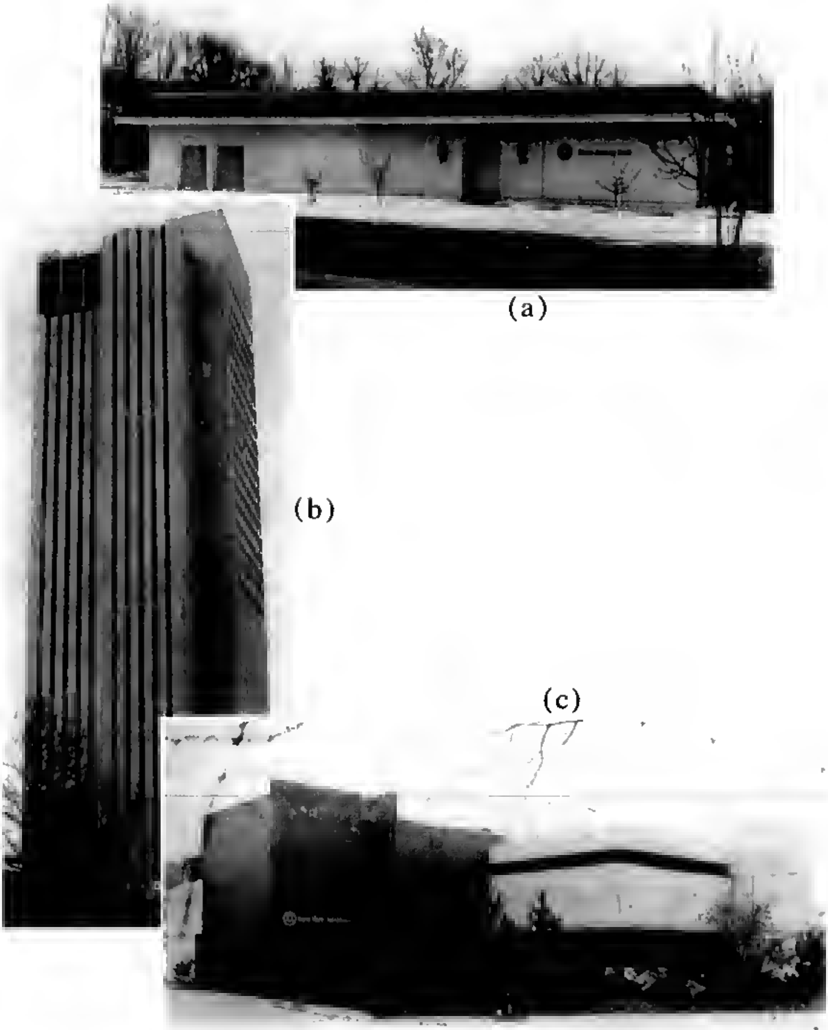


Fig. 6—NEBS central offices for 7-foot equipment. (a) Surburban switching office. (b) Metropolitan toll center. (c) Urban switching office.

and cable entrance facilities. The environmental requirements are grouped according to functional effects and include thermal, fire resistance, shock, vibration, earthquake, airborne contaminants, grounding, accoustical noise, illumination, and radio frequency interference. Standards, design requirements and planning guidelines exist in the NEBS documents for each equipment area in the building and for all the building support systems and structure.

Of principal note is the height standard of 7 feet for all new electronic equipment systems. Because of the compact electronic equipment, a

standard decrease in the floor-to-floor height of the building is possible for all new Bell System central offices and leads to substantial savings. For each foot the clear ceiling height is reduced, the cost per square foot of space in a multi-story building decreases by about 4.5 percent. When the overall expense for a central office building designed to the older high bay standards is given a reference value of 1.00, the relative cost for a similiar building to house 7-ft frames is 0.92, or an 8 percent overall cost saving. The curves in Fig. 7 show that, for a 7-ft frame, costs are at the reference level when the floor-to-floor height is 15-½ ft. But these costs decrease with decreasing story height. At a floor-to-floor height of 14-½ ft, the costs are 96 percent of the reference level, and at 13-½ ft, (the NEBS standard floor-to-floor height), costs are only 92 percent of the reference level. Additional savings result from less stringent requirements for floor loading, from more compact floor plans, more accessible cable racks, and more efficient lighting, and from eliminating some supports and ladders used with taller frames.

The allocation of vertical space on a floor and the partitioning of the allowable floor load for NEBS equipment space is listed in Table II. To encourage the efficient use of the floor area in buildings, standard floor plans are available for each of the major types of equipment. The NEBS standard floor plan for 12-in. deep equipment frames is shown in Fig. 8, where five line-ups per building bay are indicated. Cable holes, miscellaneous frames, power equipment, and a process cooler can be located in a sixth line-up at the column line. In most equipment areas, the 2-½ ft maintenance aisles and 2-ft wiring aisles provide adequate space for operation, maintenance, and cabling.

The vertical space allocation is shown schematically in Fig. 9, where equipment and two identifiable cable systems are placed under the 10-ft clear ceiling. Cable pathways are designated for system cabling and

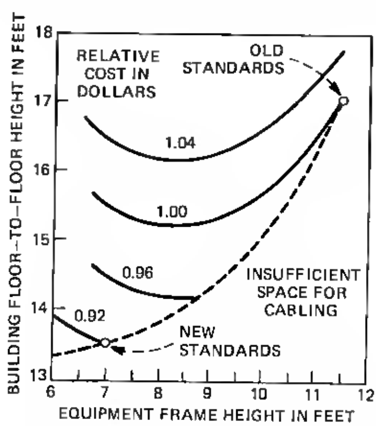


Fig. 7—Cost study for NEBS standards.

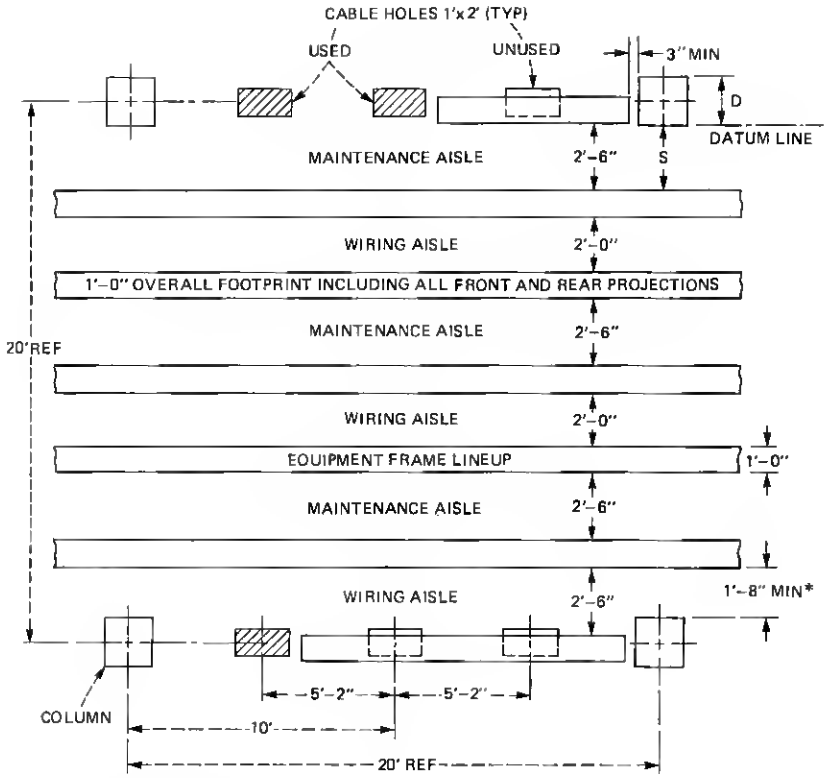
Table II—NEBS equipment space and load allocations

Equipment	Vertical Space	Floor Load
Equipment Frame Area:		
Frames	Floor to 7 ft	115 psf
Cable distribution system and installation clearances (includes allocation of 5 psf for via CDSS)	7 to 10 ft	25 psf
Power Area:		
All equipment, cable, and installation clearances	Floor to 10 ft	140 psf
Distributing Frame Area:		
All equipment, cable, and installation clearances	Floor to 9 ft	135 psf
Via CDSS	—	5 psf
Cable Entrance Area:		
All equipment, cable, and installation clearances	Floor to 10 ft	140 psf
Operations Support Systems Area:		
All equipment, cable, and installation clearances	Floor to 10 ft	140 psf
Conventional Cooling System:		
Overhead ducts and diffusers	10 to 12-½ ft	—
Modular Cooling System:		
Raised floor	Floor to 1-½ ft	10 psf
Supply, return, and drain piping	Floor to 1-½ ft	—
Process coolers	1-½ to 11-½ ft	115 psf
Suspended ceiling	11-½ to 12-½ ft	—
Transient Loads	—	10 psf

via cabling, that which joins and powers the various systems throughout the building. Pathways for three levels of cable racking occupy the 7-ft to 10-ft space with provision over the life of the equipment-building system for lights, openings for cooling air, and installer access. The application of the NEBS standards for equipment, floor plans, and cabling produces near-optimum use of space. Additionally, use of the standards simplifies building design and equipment engineering, streamlines equipment and cable installation, and allows for flexibility in growth patterns.

V. THE PLANNING OF A CENTRAL OFFICE

To achieve the special design of new equipment buildings and additions requires not only company ownership rather than leasing, but also company planning, engineering, and preparation of specifications. Figure 10 shows a typical sequence of central office planing activities. The charted durations, representative of an office of 20,000 to 30,000 telephone lines, could vary somewhat depending on circumstances associated with a particular project. A new office is an outgrowth of a continuing process called fundamental planning that is performed in each operating company by the plant-extension department. Possible patterns of growth for the residential, commercial and industrial areas of a community are studied, and predictions are made that form the basis for additions to the outside plant and the construction of a new central office. The actual location, the timing, and the expected size for the new facility are interrelated study factors. Minimized investment is sought by decisions that balance the investment



COLUMN DEPTH "D"	SPACE AT COLUMN FACE "S"
1'–10" OR LESS	2'–6"
2'–0"	2'–4"
2'–2"	2'–2"
2'–4" OR GREATER*	2'–0"

*FOR COLUMN DEPTHS GREATER THAN 2'–4" IT MAY BE NECESSARY TO OMIT SOME FRAMES IN THE EQUIPMENT LINEUP OPPOSITE COLUMNS (WIRING AISLE SIDE)

Fig. 8—NEBS standard floor plan for principal depth (12-in.) frame.

in outside plant for the area and the investment in the equipment-building system at the wire center.

It is the plant-extension department's responsibility to perform economic studies of potential alternative solutions to handle growth situations and to make recommendations that eventually will result in either new central offices or additions to existing structures. At existing central offices, telephone usage is observed and compared against the traffic-handling capabilities of the equipment and network for the area. As telephone usage increases with time and the existing circuit capacity becomes limiting, the existing central office and network facilities must be enlarged. A management decision on the construction of a new or

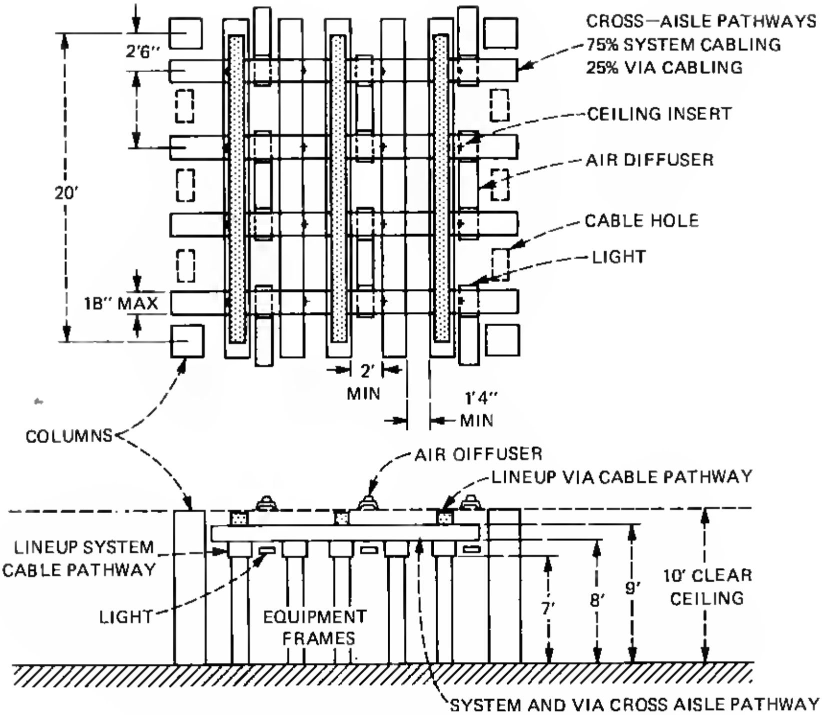


Fig. 9—NEBS cable pathways plan for 12-in. deep frame areas.

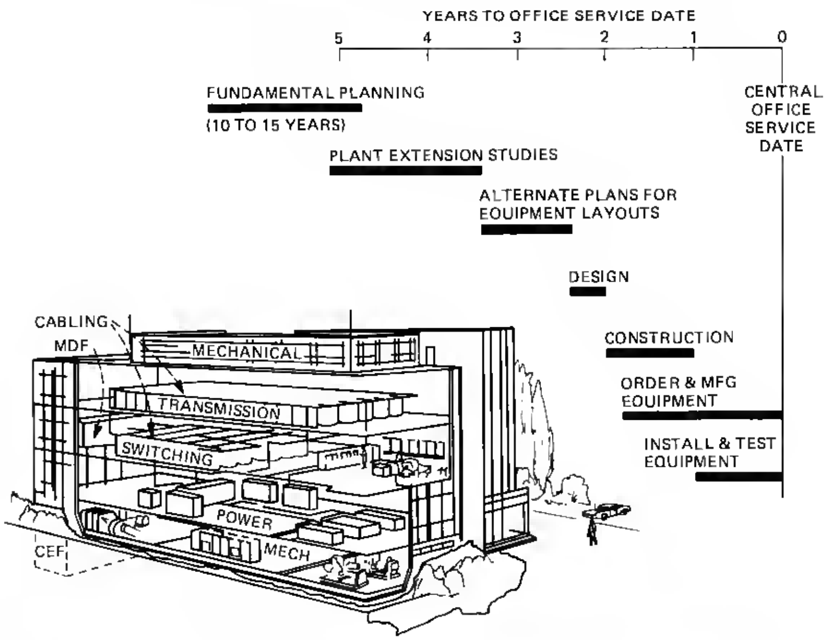


Fig. 10—Typical central office planning process. The isometric building illustration shows the types of space and equipment.

expanded facility is typically made three and sometimes five or more years before the proposed facility is put into service.

The decision to construct initiates a new-office project that will be the responsibility of other telephone company personnel, experienced not only in the equipment portion of planning but also in electrical, power, mechanical, structural, real estate, and legal aspects. The first task is to estimate equipment requirements, those for initial service and for the fully developed office. The final installation of equipment may be 5, 10, or even 20 years from the time of planning. The types of equipment that are likely to be used are local switching equipment, toll switching equipment, terminal and transmission equipment for the various toll networks that include analog and digital coaxial cable routes and analog and digital microwave radio routes, operator-service equipment, ac and dc power equipment, maintenance and administrative equipment that uses embedded minicomputers to service the telephone network, cable entrance facilities, and extensive vertical and horizontal cable-distribution systems.

The space planners must select the type and quantities of this equipment to custom-fit the service requirements of the particular central office or station, locate each of these equipment systems within the facility so that each has future growth potential without interfering with the others, and make accurate layouts from floor plan data of the individual pieces of equipment to ensure adequate spacing. Once all telephone equipment requirements are established, they become the basis for determining the capacity and physical requirements for equipment cooling, ventilation, and normal and reserve ac and dc power. The entire process requires considerable interaction with the different engineering and operating groups and may take anywhere from several months to several years. Furthermore, it is usually complicated by the fact that all planning is dependent on the telephone-usage forecast which may be amended during the planning interval and on equipment technology which is characterized by rapid changes in capability and support requirements. Finally, an architect is called upon, but only after the site of the wire center is selected and procured and study plans are completed and mutually agreed upon by the involved telephone company personnel, e.g., the planners, the equipment engineers, the building engineers, and the departments which will operate the facility.

The study plans, which show the location for all telephone, electrical, and mechanical equipment and the special structural configurations needed to accommodate this equipment, contain virtually all the basic dimensional information needed to describe the facility; that is, number of stories, floor-plan dimensions, ceiling heights, column spacing, and locations of cable-hole openings in the floors, of removable walls for future growth, of mechanical rooms and of electrical rooms. The study

plans and the design standards, such as those to control construction material quality, floor-load, floor-levelness, and capacity of the standby power and air-conditioning systems, are the basic information that is passed on to the architect who then prepares the drawings and specifications to be used by the construction contractors. In addition, the study plans go to the equipment manufacturer who also receives the contract to install the equipment and interconnect it with cable.

A typical plot and floor plan of a local electronic switching system office in Liverpool, New York, is shown in Fig. 11. Planning for this central office began in 1971 and includes considerations for equipment installations to 1985. In this building, 63 percent of the gross floor area will be used for equipment, 20 percent for ac and dc electrical systems, 15 percent for mechanical systems, and 2 percent for nonequipment purposes. It is apparent from these plans that the goal of a fully integrated and interrelated equipment-building system is achieved.

VI. SPECIAL FEATURES OF CENTRAL OFFICES AND TRANSMISSION STATIONS

Although modern central offices and transmission stations vary greatly in size, similar features appear in all of them. From the small local office and repeater station to the large multistory toll office and main station, the basic elements of the equipment-building system are repeated. The special features are required to facilitate the interconnection of internal and external cables and wires, to support and position the equipment, to power the circuits, to obtain proper environmental control, and to provide for installation, maintenance, and operation.

Detailed information about the more prominent features in the modern equipment building is given below, with illustrative photos of the larger facilities.

6.1 Cable entrance facility

As a wire center, the central office must have provision for bringing in thousands of pairs of wires. Similarly, provisions must be made at stations along coaxial cable routes for the entrance of cable and at radio stations to support the waveguide between the antenna and the equipment. A medium-sized central office cable entrance facility (CEF) is shown in Fig. 12 in a below-grade situation. The CEF is a vault-like area typically 12 to 15 ft high, 12 ft wide, and the length of the central office directly under the main distributing frame. It can be over 200 ft long. One or both of the end walls contain a conduit termination with its built-in gas-venting chamber that is employed to guard against water and hazardous gas entering the central office. As shown in Fig. 12, the terminating conduit formation provides an entrance area for

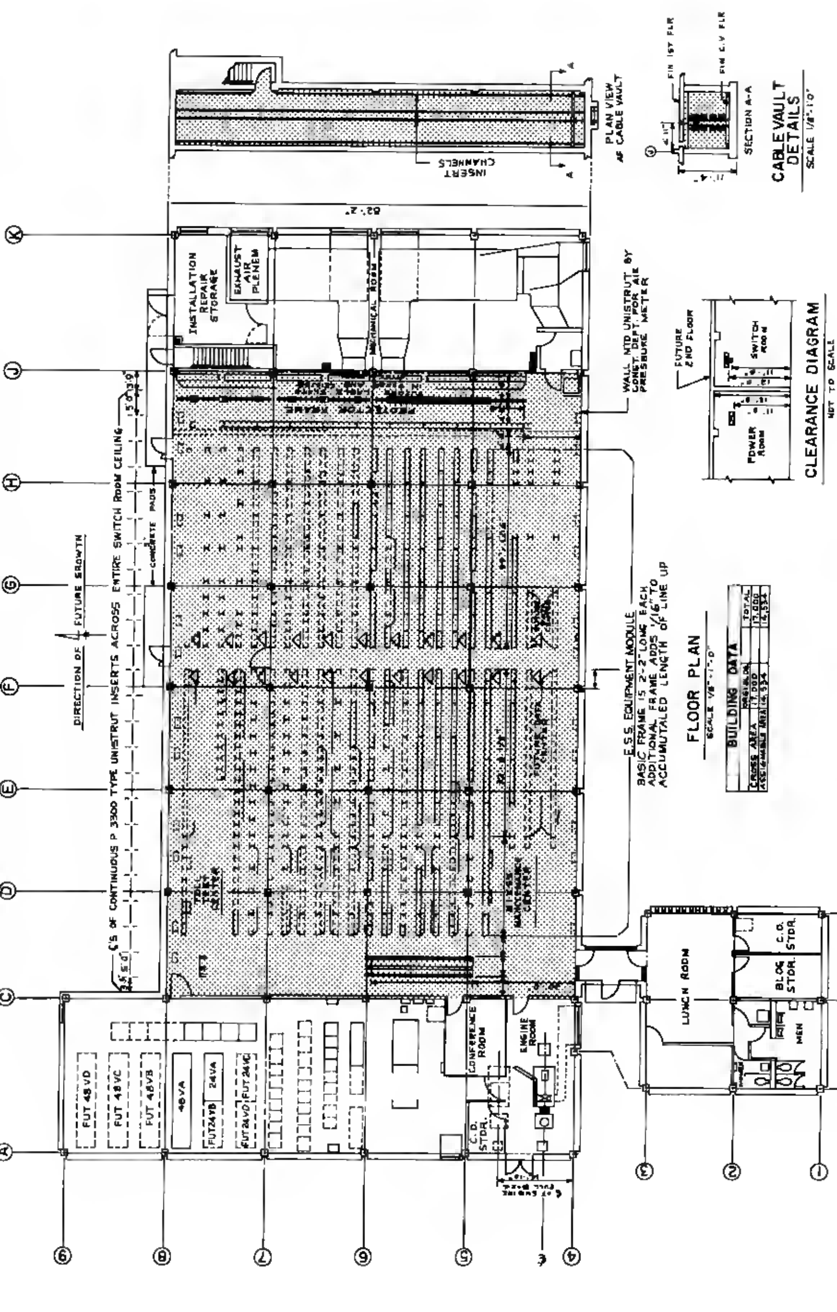


Fig. 11—Central office study plan.

Fig. 12—A subgrade cable entrance facility with provision for cable penetration through basement walls, ceiling, and the outer wall to upper floors.

multiconductor cables, each approximately 3 inches in diameter. These cables are placed on steel support racks that are attached to the long walls, and brought to a location where they are needed upstairs on the main distributing frame. At this point, the cables are spliced to smaller terminating stub cables and routed upward through a ceiling penetration. This is the usual situation, but sometimes riser cables are directed to upper floors through conduits or shafts in the outer wall. Also, local site conditions, such as a rock ledge, high water-table level, or the projected size of the facility may preclude the use of a sub-grade structure. In such cases, the CEF is constructed paralleling the distrib-

uting frame and the outside-plant cables are brought into the office at grade level through a conduit structure built adjacent to the office.

These cable entrance facilities for underground feeder, trunk, and toll cables also provide space and structural support for the following:

(*i*) Pressurization of outside-plant cables to prevent moisture from penetrating the inner core of the cable.
(*ii*) Isolation of dc potentials for corrosion protection.
(*iii*) Grounding of cable shields for electrical protection and noise reduction.
(*iv*) Installation of splices between the feeder cable coming from the outside plant and riser, stub and bridging cables going to distributing frames.
(*v*) Routing of feeder, riser, and terminating stub cable including required cable spreading.
(*vi*) Cable-placing activities including provisions for pull-in irons, feedholes, and work platforms.

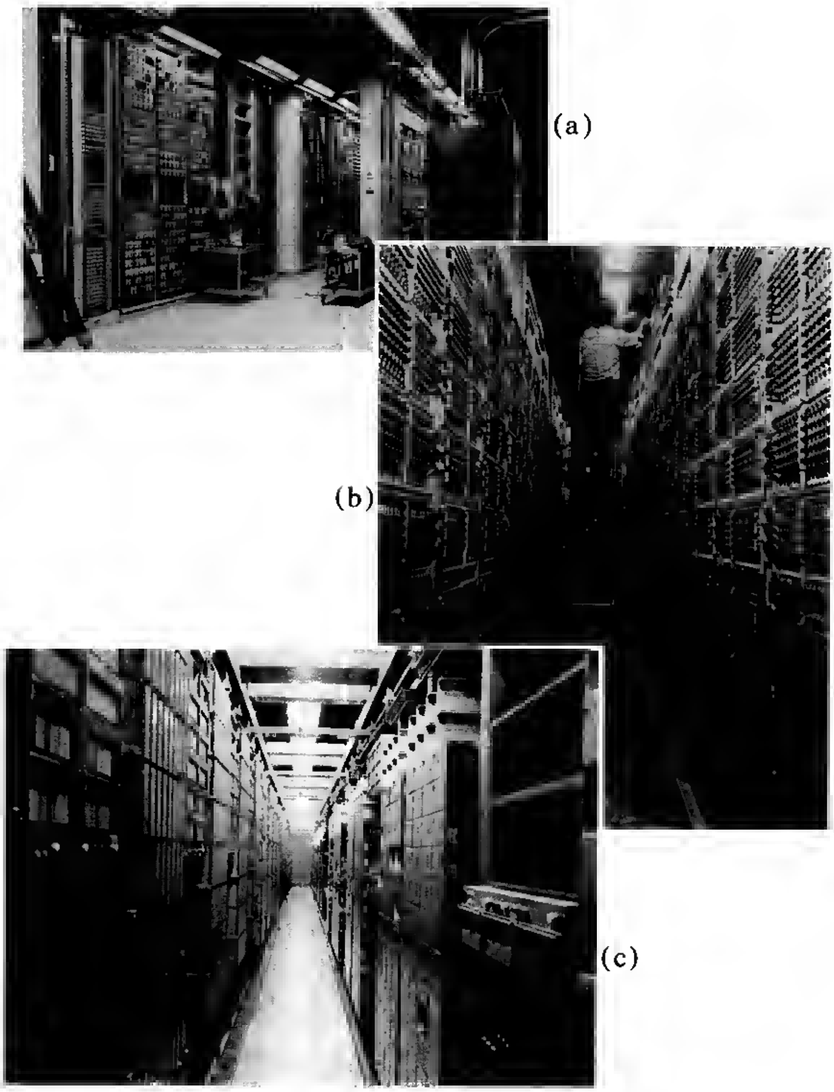
6.2 Telephone equipment areas

Approximately 60 to 85 percent of the interior space in a central office consists of telephone equipment areas. These are large, usually windowless, partitionless rooms designed to contain the equipment, the appropriate cable support systems, and the air ducts for environmental control needed for the equipment to function. The switching and transmission equipment installed in these areas are usually mounted, as shown in Fig. 13, on steel frameworks that are 1 to 2 ft deep and up to 6-½ ft wide. The frames are installed side by side in lineups usually 30 to 50 ft long and, because of the enormous size and weight, are bolted to the floor or ceiling or both with concrete-embedded anchors to prevent vibration and toppling.

The aisles between each lineup are typically between 2 to 4 ft wide and are used for access to the equipment for wiring and maintenance. Above the equipment frameworks are other steel structures that support tons of cabling which connect the equipment together and to the distributing frames.

The main distributing frame, shown in Fig. 14, is also in the equipment area. Distributing frames are the wiring interfaces between the subscriber plant and toll cables that enter through the CEF and the telephone switching and transmission equipment. In multistory offices, distributing frames and equipment are on a number of floors; therefore, vertical access for cables must be provided. Many heavy bundles of interfloor cabling, as shown in Fig. 15, are used. In the equipment area, steel frameworks are positioned between floors to support the vertical cabling and special reinforcement is employed in the floors to maintain structural integrity at points of penetration.

The dc power cabinets and batteries that provide the power conversion and uninterrupted energy source for the telephone circuits are also located in equipment areas but are usually separated in power rooms from the transmission and switching equipment. Power equipment occupies approximately 10 to 15 percent of the gross equipment area and consists of lineups of lead-acid batteries, as shown in Fig. 16, and cabinets of electrical equipment such as rectifiers, converters,

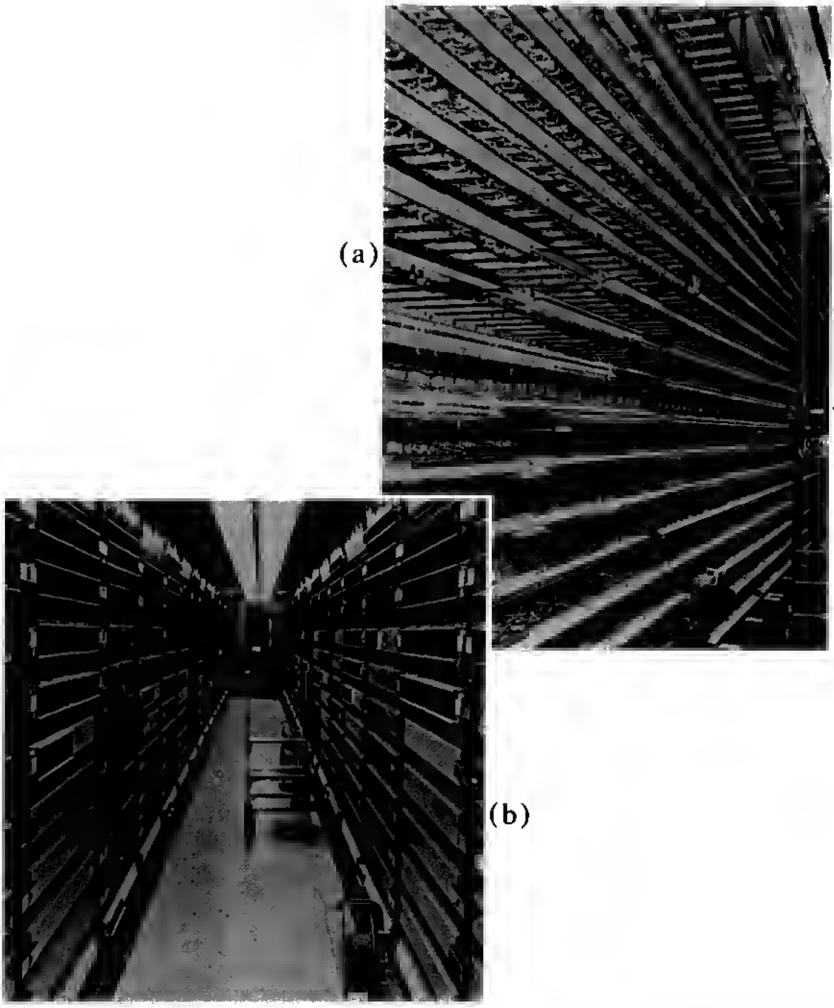


(a)

(b)

(c)

Fig. 13—(a) Toll equipment and (b) crossbar switching equipment mounted on 11-½-ft frameworks. (c) ESS equipment mounted on 7-ft frameworks.



(a)

(b)

Fig. 14—The main distributing frame, the wiring interface between outside plant cables entering cable vault and the telephone equipment. (a) 12-½-ft MDF used with 11-½-ft frameworks for central offices. (b) 8-ft COSMIC MDF used with 7-ft modern electronic equipment.

panels, and service boards that control the distribution of power. The batteries and the associated overhead power distribution bus bars are assemblies typically 2-½ ft deep, 10 to 15 ft wide, up to 9-½ ft high and weigh about 10 tons per 50-kW module.

The spatial and weight characteristics of the different types of telephone equipment described above impose special design conditions on the structure. The more important structural design requirements for the modern Bell System equipment buildings are summarized in Table III, along with values used in a typical office building.

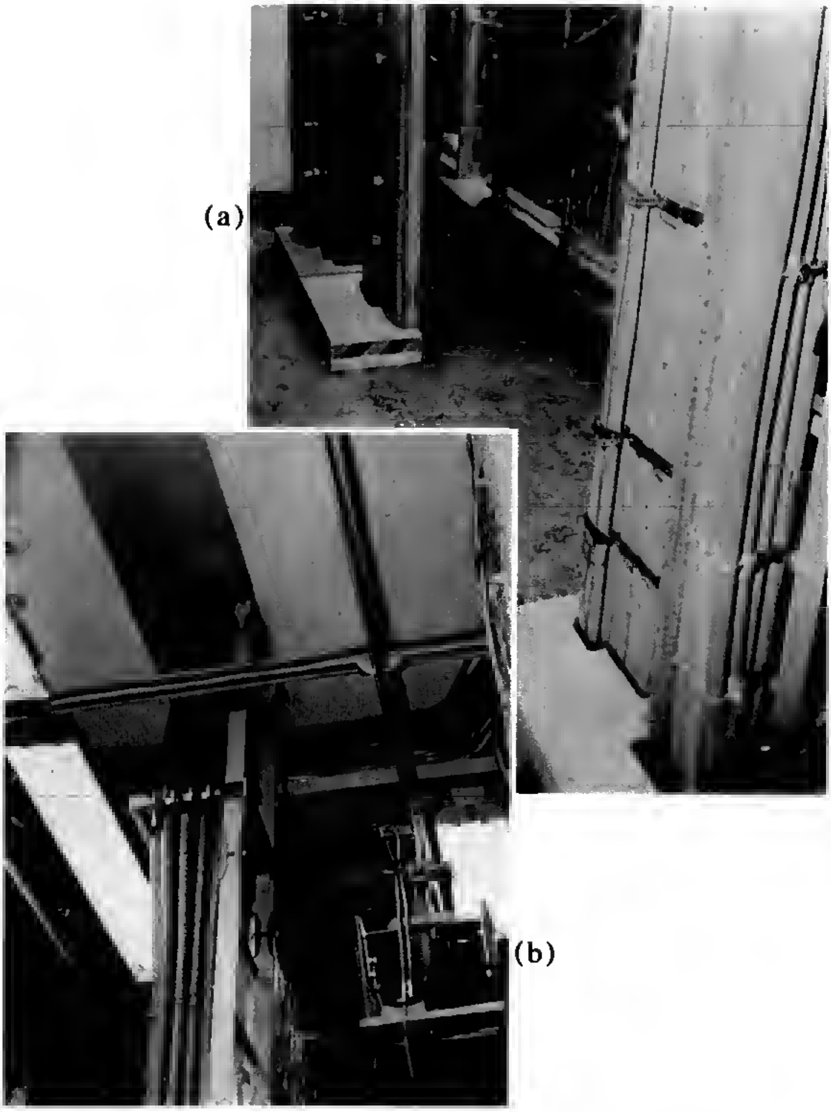


Fig. 15—Telephone equipment rooms, showing cable routed above the frames and from one floor to another.

6.3 Electrical systems

In addition to the dc power that directly serves the telephone equipment, there are a number of other special electrical features. Their design and construction are characterized by the need for extreme reliability and high capacity. The electrical systems provide means for uninterrupted service under all types of emergency condi-

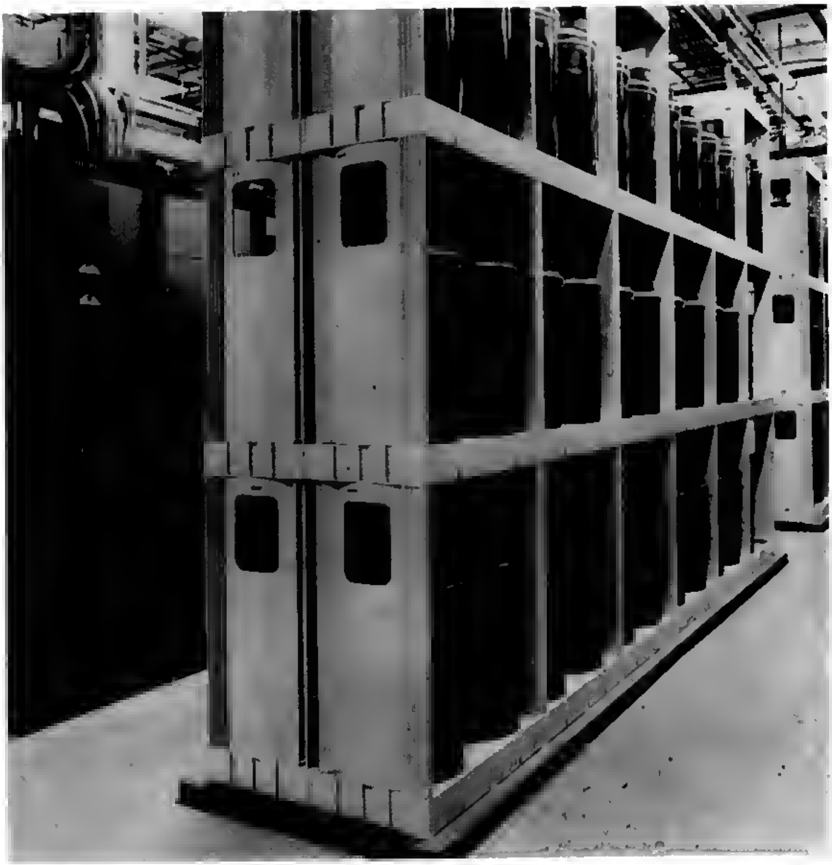


Fig. 16—Central office battery plant with dc control and distribution cabinets.

tions. Additionally, special control and protective circuits are employed. The variety and composition of the electrical systems are as follows:

(*i*) The ac power system consists of an entrance transformer for utility power, switch gear for primary distribution, motor-control centers, branch circuit protection equipment and conductors, switchboards, service cabinets, and bus-duct cable assemblies. These elements are necessary to power the central office telephone lines, terminals, and equipment under normal operating conditions. Additionally, the ac power system serves the mechanical systems that heat or cool the equipment.

(*ii*) An emergency system, shown in Fig. 17, is employed to provide power in the event of failure of the commercial source. Provisions exist to transfer all circuits to locally generated or reserve power. Typically, one or more diesel- or turbine-driven alter-

Table III—Structural characteristics

	NEBS Telephone Facilities	Office Buildings
Floor load*	150 lb/ft†	75 to 100 lb/ft†
Maximum deflection†	½ in.	1 to 2-½ in.
Floor levelness‡	±⅛" in 8 ft	±¼" in 10 ft
Column spacing*	20 ft	30 to 50 ft
Ceiling height§	12-½ ft	8 to 10 ft

* Floors must be able to support loads of at least 150 lb/ft^2 throughout the entire structure and higher in the areas where certain battery plants and mechanical equipment will be located. To achieve the most economical design to carry these heavy live-loads, column spacing in NEBS buildings is 20 ft rather than the 30 to 50 ft commonly found in office buildings. The net effect is that floors and foundations are massive, and there are 2 to 3 times more columns than in conventional buildings.

† A criterion related to floor strength is the maximum deflection under load. For telephone structures, it must be less than ½ in. to avoid creating additional problems involved in leveling and aligning the equipment units. For conventional buildings, the lighter floor slabs may deflect 1 to 2-½ in. under design loads, depending on local building codes.

‡ For proper structural support and to simplify installation of equipment frameworks, floor levelness from high to low points must be within 1/4 in. in 8 ft, 3/4 in. in 20 ft, and 2 in. over the entire floor area. In conventional buildings, the floor-levelness requirement is less stringent than ±1/4 in. in 10 ft.

§ The height of equipment frames and the need for clear overhead space for cabling and process cooling-air distribution assemblies require higher floor-to-ceiling heights under all obstructions than usually provided in conventional office buildings.

nators, shown in Fig. 18, are provided with the necessary ac switch gear to transfer loads from the normal ac power system to the reserve system. The heavy diesels impose extreme loads on the structure and can be a source of vibration that can damage equipment; therefore, special protective structural design features are required. Additionally, support systems for fuel, air intake, and engine exhaust are necessary. A special fuel supply and storage system is provided that permits at least three days of central office operation during commercial power-failure emergencies. The air-intake systems are large, consistent with the high capacity of the emergency diesel engines and turbines, and the structure and equipment areas must be protected from the effects of the high-temperature exhaust with special insulating assemblies. Exhaust silencers must be used with diesel and turbine plants to eliminate much of the noise that would otherwise be radiated from the engines and that would be objectionable to the building occupants or neighbors.

(*iii*) Extensive electrical grounding systems are placed throughout each building for the purpose of eliminating noise on lines, reducing high-speed data errors, and protecting the telephone equipment from electrical short circuits and lightning strikes. The ground circuits connect all steel in the structure and in the equipment frameworks with a connection to the earth. Certain electronic equipment requires dedicated grounding arrange-

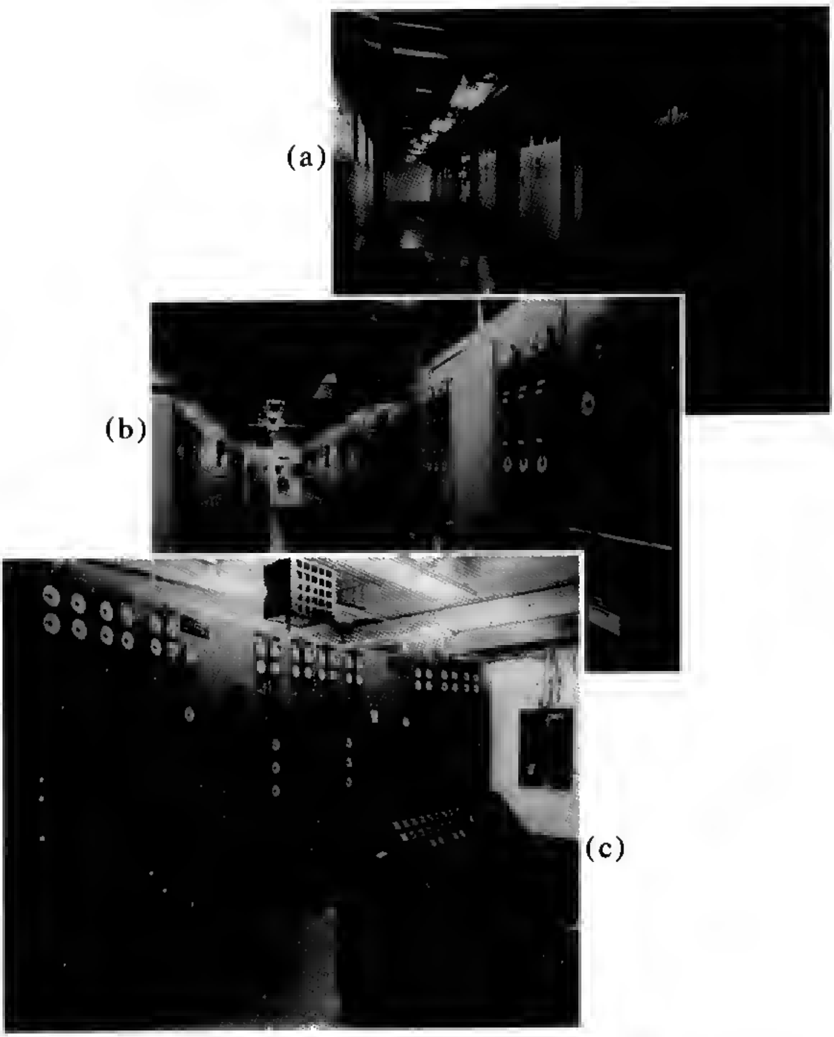


Fig. 17—AC service equipment in a large central office. (a) Stepdown power transformers reduce engine-alternator voltage to commercial power level. (b) AC switching gear transfers power from commercial to engine-alternator standby sources. (c) Mimic panel for remote control of ac equipment.

ments in addition to that provided by the building grounding system to avoid circuit malfunctions.

(*iv*) Shielding systems are provided in offices located near sources of high-intensity electromagnetic or electrical fields such as radio broadcasting stations, electrical power stations, or certain high-tension lines. Shielding prevents electromagnetic fields from penetrating and causing malfunction of electronic equipment. Figure 19 is an example of an internal shield. Wire mesh is embedded into the precast concrete wall and roof panels

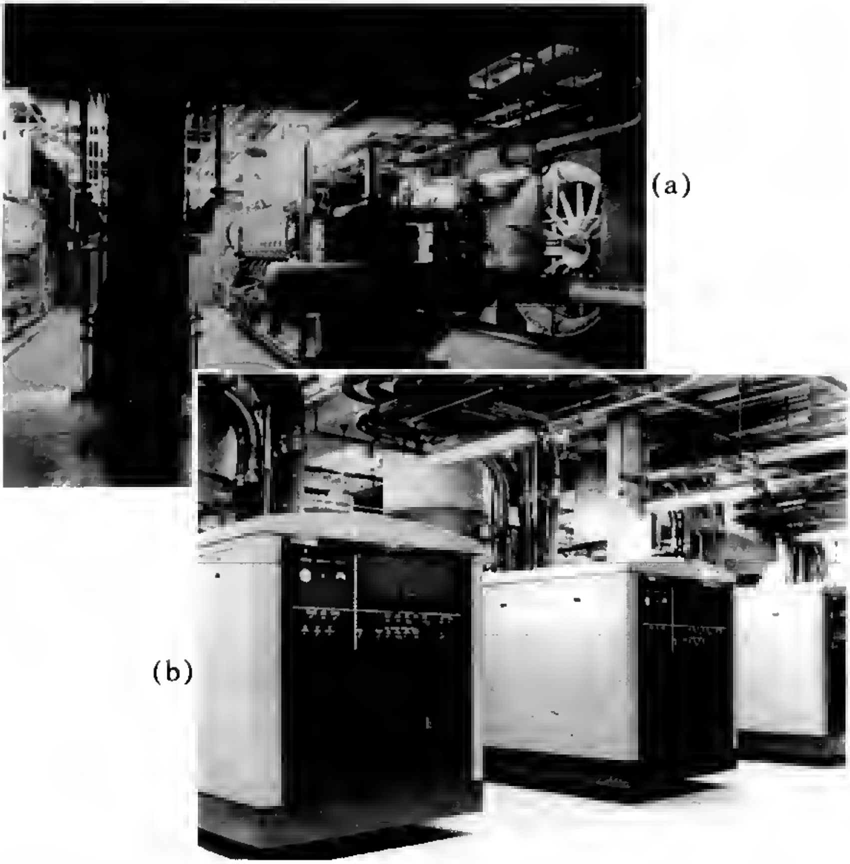


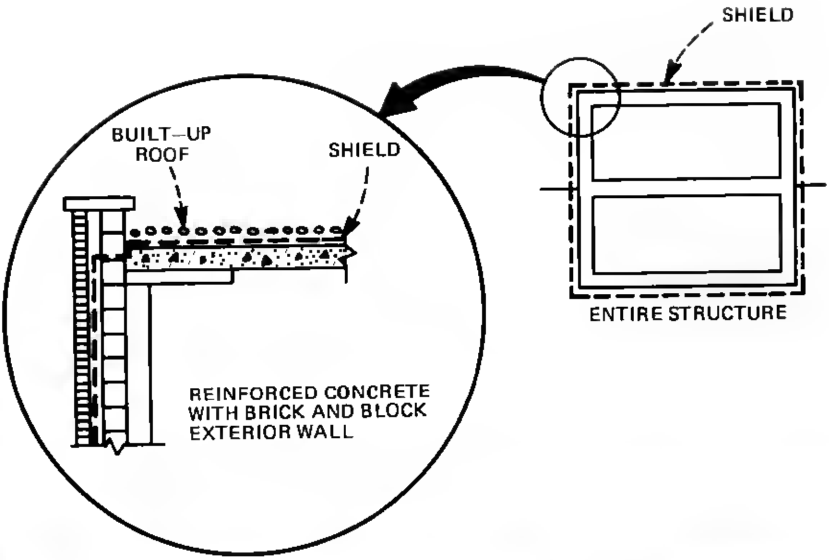
Fig. 18—Standby engine alternators. (a) 2500-kW diesels. (b) 750-kW turbines.

used in this type of construction. Shields are also obtained by welding the reinforcing bars of the structure to form a conducting cage, or by placing and joining copper or steel sheets either on the inside or outside of the structure to form a complete metal enclosure.

(*v*) Extensive detector, alarm and control systems, as shown in Fig. 20, are employed throughout the building for protection against circuit and service impairment due to fires. These are especially important since automatic water sprinkler systems cannot be placed in equipment rooms because of the great hazard from water to the electrically powered equipment.

6.4 Mechanical systems

Equipment buildings have mechanical systems to provide temperature control, to regulate the humidity of the surrounding air, to maintain appropriate amounts of outside air of high purity, to provide



(a)

(b)

Fig. 19—Construction methods for protection against radio frequency interference. (a) Building encased in continuous sheet-metal shield. (b) Panels precast with embedded galvanized mesh.

means for vertical access in multifloor structures, and to provide movement of air, water, and fuel. Mechanical equipment areas take from 5 to 25 percent of the gross space, depending upon the provisions for process cooling, humidification, and air filtration needed by the

Fig. 20—Fire and mechanical equipment alarm panels. Left: Remote-control panel for equipment cooling systems. Rear: Flow alarms for fire extinguisher lines. Right: Smoke alarm panels and controls to operate dampers and evacuate smoke through ventilation system.

telephone equipment and reserve power engines. The variety of mechanical equipment systems are:

(*i*) Large refrigeration rooms are required in central offices because the cooling systems are designed to remove heat, released from telephone equipment, that can range up to 100 watts per square foot of occupied floor area, depending on the type of equipment installed. The range in heat released over one building bay of 400 square feet in local crossbar and electronic offices and for toll electronic offices is shown in Fig. 21. Recent telephone equipment developments have been aimed at miniaturizing components through the use of solid-state electronic devices. This close-packed equipment dissipates large amounts of heat and, therefore, requires exceptional amounts of cooling. For example, a 10,000-square-foot toll office will require up to 100 tons of cooling capacity when it houses electronic transmission and switching equipment. Conventional office buildings with equivalent floor area requiring cooling for human comfort would rarely be provided with more than 15 percent of this air-conditioning tonnage. Most equipment buildings have very large mechanical rooms close to the equipment areas to accommodate the high-capacity fans, chillers, chilled water and condenser water pumps, and chemical water-treatment tanks. Also, because of the high-heat dissipation, cooling is often required all year, even in northern regions, and naturally the heating plants in these structures are minimal. Figure 22 shows a portion of the chillers for the cooling system of the 323 Broadway, New York, office.

(*ii*) The ventilating fan systems are of sufficient capacity so that,

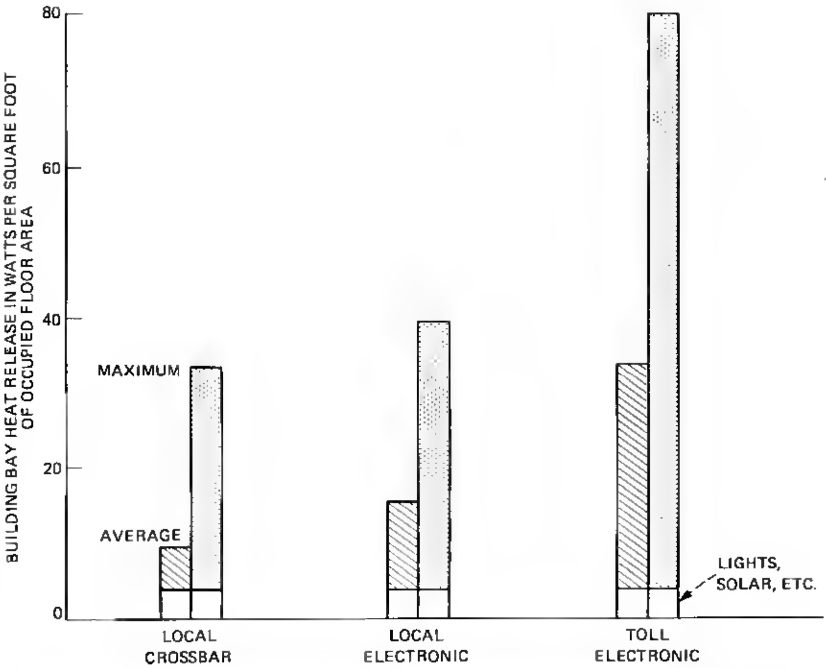


Fig. 21—Heat release in modern central offices.

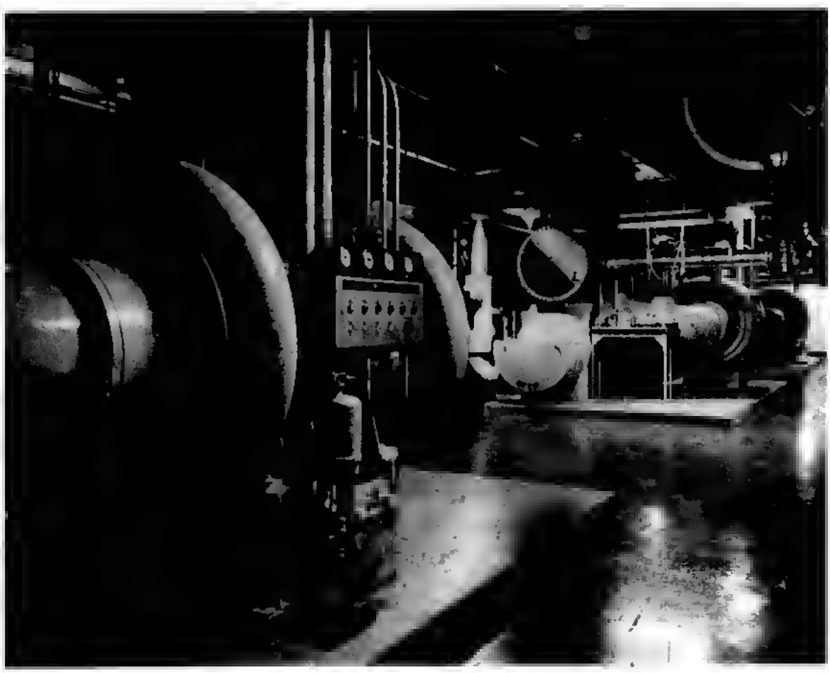


Fig. 22—Three 600-ton chillers for telephone equipment cooling.

in the event of a refrigeration-plant failure, short-term ambient operating environments for the telephone equipment can be maintained by the use of outside air while repairs are being made. The systems are characterized by elaborate air-ducting assemblies that have terminal diffusers aligned closely with the equipment lineups. The extensive overhead ducting in a new structure for this type of cooling system is shown in Fig. 23. Alternately, modular cooling systems comprised of a raised floor, plenum ceiling, and process coolers are employed to remove heat from the equipment room. In this type of system shown in Fig. 24, conditioned air is injected into the room through slots in the plenum ceiling, is heated by the equipment, and returns through slots in the raised floor to the process cooler fan-coil assemblies that remove tbe excess heat and return the air to the ceiling. Due to the quantity of air that is exchanged to remove the heat from the equipment space, large air-intake chambers, fans, plenums, and exhaust ducts are required. The air inlets shown in Fig. 25 illustrate the size of this air-handling equipment in a large facility. The fan room of a toll office and one of the machines used to pressurize the air distribution system are shown in Fig. 26. In addition to air for equipment cooling, special features are needed to provide for the large quantity of cooling and process air required by reserve engines and turbines that are also located within the building.

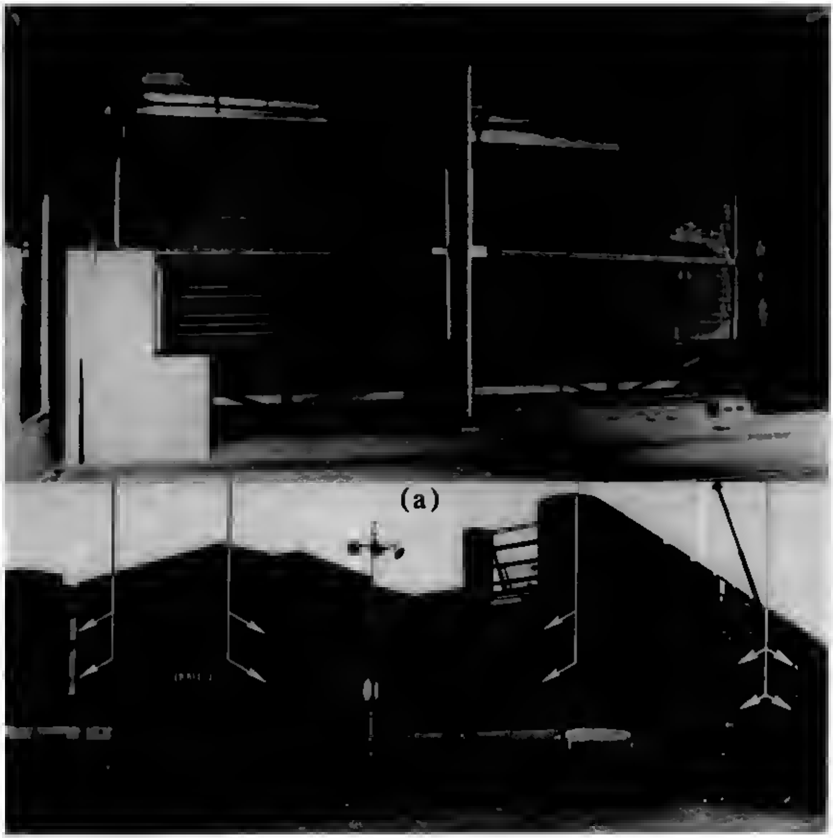
(*iii*) All the air required for process control is subject to quality standards to reduce the adverse effects of contaminants on the equipment and reserve power plants. High-capacity air filtra-

Fig. 23—Extensive overhead ducting to cool high-heat dissipating telephone equipment.

Fig. 24—Equipment room with a modular cooling system (raised floor, plenum ceiling, and process coolers in the column line).

tion systems, shown in Fig. 27, are necessary to prevent dust and products of combustion from infiltrating the building to cause electrical contact failures. Where extreme levels of air pollution occur, special high-efficiency filters are employed to remove potentially damaging material. Because of the volume of air that must be handled for ventilating the equipment rooms, large support frames are necessary for mounting the filters. These in turn require that significant space be provided in the basic structure of the facility to accommodate the air filtration plant.

(*iv*) Vertical access space within the structure is provided for the routing of all water and drain lines used to interconnect the elements of the mechanical systems that are located on different floors. Vertical access provision is also provided for the fuel lines and exhaust stacks of the engines of the reserve power plants that may be located in below-grade rooms, on intermediate floors, or on the roof of the central office. The location of the vertical runs is coordinated with the equipment plan so as not to interfere with the subsequent placement of future generations of equipment, while special provisions are made so that leaking fluids offer the least hazard to telephone equipment. Vertical access is also provided to permit the movement in the building and to upper floors of the large bulky equipment



(b)

Fig. 25—Air inlets and exhausts for removing large amounts of heat released from equipment in modern central offices. (a) Interior of an inlet port. (b) Central office with 16 air inlet and exhaust chambers (10 visible).

assemblies that are added periodically to handle increases in demand for service. Large loading docks, freight elevators, or hoisting shaftsways are used to transfer and move the heavy loads, and dedicated open areas adjacent to equipment rooms are needed for the uncrating and erection of the equipment assemblies.

6.5 Special construction

Another very important characteristic of a central office or transmission station is the provision for expansion. If a horizontal addition is anticipated, the rear or a side wall must be designed for removal without interfering with the structural integrity of the roof and floors or with equipment assemblies that are operating to provide service. Also, extensions to the air distribution ducts and refrigeration machinery of the process cooling system must be accommodated. Virtually

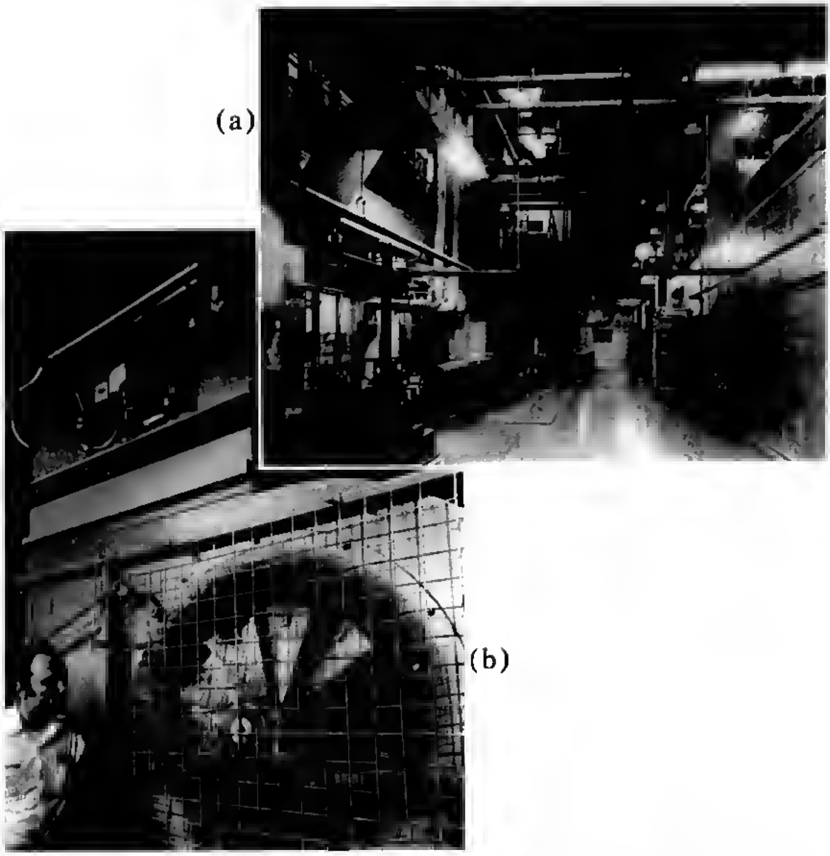


Fig. 26—Mechanical room in large central office for pressurizing chilled air to cool equipment. (a) Sheet-metal wall, portion of fan plenum that houses 6 fans. (b) One of the fans in the plenum.

every study plan for an office or station shows the planned growth directions. If vertical additions are anticipated, the footings, columns, and load-bearing walls must be adequate for the ultimate structure, and this will necessitate what appears to be greatly oversized initial construction as indicated in Fig. 28.

Special construction is also required where offices have roof-mounted microwave radio towers, as shown in Fig. 29. The typical means of transmission for many toll routes is by point-to-point microwave radio. This is particularly true when toll offices are located in metroplitan or other areas where installation of underground cables between offices is costly. Such towers must be capable of supporting several antennas and the composite assemblies weighing hundreds of tons. With the tower and antennas on top of the building, the load is carried through the building to the foundation of the structure and

Fig. 27—High-efficiency filter banks for processing air for ventilation, for equipment cooling system make-up air, and for standby-engine air supply.

requires a massive internal support system. Additionally, vertical access for waveguide, power and personnel, and appropriate fascia must be provided until the time when the antenna support tower is enveloped by vertical additions to the wire center or transmission station.

VII. SUMMARY AND ACKNOWLEDGMENT

During the 100-year history of the telephone, three different sets of building design standards have been used in the Bell System. The earliest central offices were designed primarily for operator switchboards. In the mid-twenties, building standards were changed to accommodate tall equipment frameworks. These controlled the design of central offices and stations until the early 1970s, when the NEBS standards were adopted. During the later decades, advances in technology permitted the reassignment of most operators and craftspersons to locations remote from the switching and transmission equipment so that, today, the central office and station are designed primarily for equipment. In those few areas where operating support systems require the presence of craftspersons, the new standards permit building operating rooms to have very attractive interior design.

Modern equipment buildings have many special design features that set them apart from conventional buildings. The special features occur because of the need to provide a dedicated operational environment

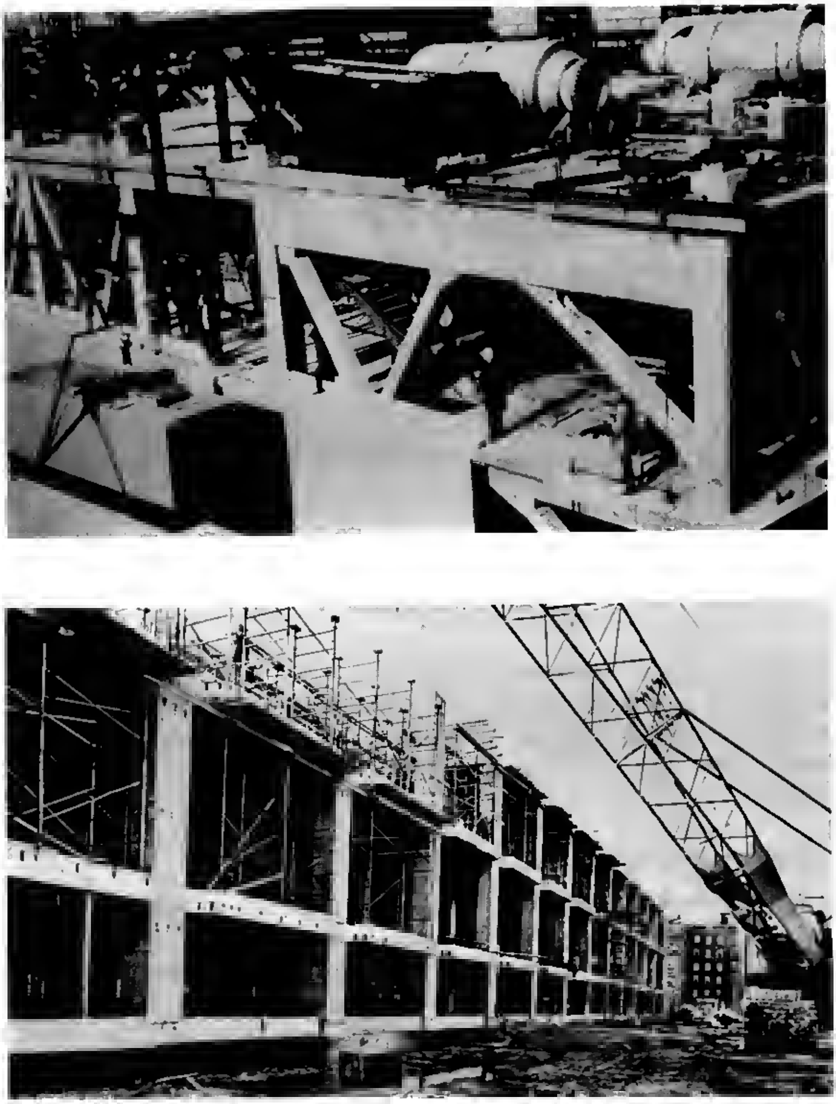


Fig. 28—Massive structural elements required for heavy equipment loads and future vertical expansion.

for the cable, wire, equipment, and apparatus that are assembled in the central office or transmission station. Once installed, the circuit elements and the mechanical, electrical, and structural elements function under the control of operations support systems as an equipment-building system that becomes an integral and vital part of the telephone network.

Fig. 29—Enclosed radio tower, with vertical access provisions and antenna waveguide systems, erected on an equipment building.

VIII. ACKNOWLEDGMENTS

While this paper has described in detail physical and environmental aspects, I wish to acknowledge the human dimension in the evolution of telephone equipment buildings. In this paper, I have had the opportunity to be the recorder of the work of many engineers and technicians who have worked in this field over many years. As chairman of the BTL Equipment-Building Task Force, I had the pleasure of working with many Bell Labs physical design engineers who are the originators and developers of tbe variety of equipment systems that are described in this paper. The development of the NEBS standards was in itself a ten-year program that owes much to the efforts of R. J. Skrabal and J. P. White, the members of their supervisory groups, the members of the Task Force, and the AT&T-WE-BTL NEBS Implementation Committee, chaired by D. M. Byrd. Many operating telephone company space planning and building engineers who are responsible for the planning, design, and construction have provided valuable information about their buildings. Finally, recognition is due L. W. Fagel for obtaining the many excellent photographs used to show the various equipment and for his study of the many special features of Bell System telephone equipment-building systems.

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